Concealed Threat Detection at Multiple Frames per Second

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We are investigating the science and technology of real-time array imaging as a rapid way to detect hidden threats through obscurants such as smoke, fog, walls, doors, and clothing. Our purpose is to augment the capabilities of protective forces in concealed threat detection, including people as well as weapons.

Among other attributes, ultra-wideband (UWB) can penetrate and propagate through many materials, such as wood, some concretes, non-metallic building materials, and some soils, while maintaining high range resolution. We have built collaborations with university partners and government agencies. We have considered the impact of psychometrics on target recognition and identification. Specifically, we have formulated images in real-time that will engage the user's vision system in a more active way to enhance image interpretation capabilities.

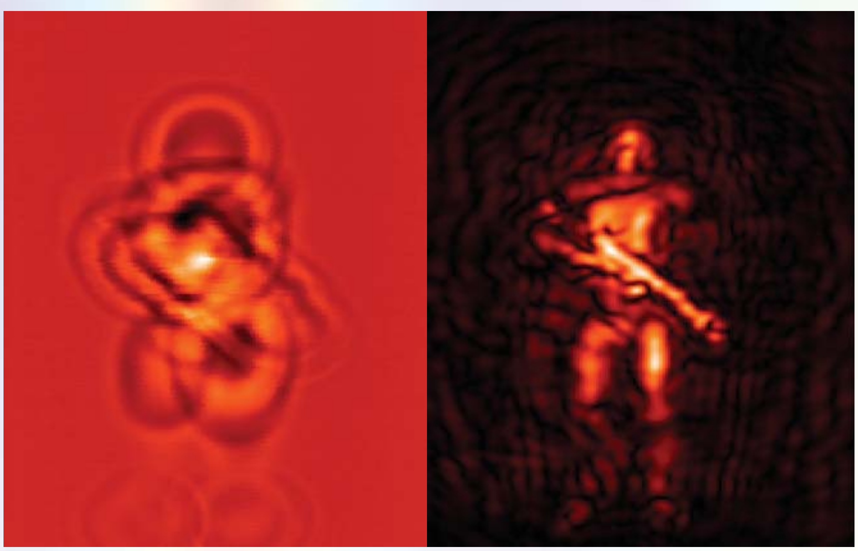

Figure 1. Sample frames from UWB radar imaging of a man holding a rifle 1 m down range. Left: image from simple Hugh transform. Right: image from a computationally intensive reconstruction algorithm.

Project Goals

We evaluated the ability of real-time UWB imaging for detecting smaller objects, such as concealed weapons that are carried by the obscured personnel. We also examined the cognitive interpretation process of real time UWB electromagnetic images. The specific goals included:

1. Develop/test a real-time array imaging simulation tool from existing static codes.
2. Research new image processing methodologies and potential algorithms that can be preformed in real-time, and demonstrate the benefits from real-time visualization.
3. Build one or more scaled-down laboratory arrays based on the most advanced field-programmable gate arrays (FPGAs).
4. Use the simulation tool to test the sensitivity of various array designs.
5. Measure the capability of human visual perception in real time versus static imaging, under various conditions.
6. Develop a plan for implementation of a full array for human perception studies and potential sponsor demonstrations.

Relevance to LLNL Mission

LLNL has an interest in improved weapons detection. A real-time radar camera will be an enabling scientific achievement because it will be unique in the world, and it will have enormous applicability.

FY2004 Accomplishments and Results

To meet our goals, we have developed a numerical imaging algorithm and implemented it to study UWB beam forming and steering. We have been successful in developing a computational simulator system to evaluate and predict the performance of the imaging system. The simulator is capable of generating impulse radar images of moving targets with arbitrary trajectories. It is capable of facilitating parametric studies of the effects of transceiver element configuration. It has been used to guide us in anticipating and benchmarking what information the laboratory prototype system should be acquiring.

Further, we have been successful in building the laboratory prototype radar camera hardware, and we subsequently used it to study and characterize UWB image generation (see Fig. 1).

We have collaborated with the DoD in characterizing the behavior of UWB electromagnetic signals through various building materials, and to assess the capability of imaging through such materials. A provisional patent application has been put in place.

To evaluate the physical characteristics and limitations of using UWB signals for imaging, we further quantified and demonstrated the effects of UWB beam forming and focusing ability. Figure 2 shows a case comparison of the effect of bandwidth on the ability to focus UWB signals. It clearly demonstrates that a large bandwidth is not only desired, but also required to enable focusing.

We evaluated the effect of array configurations that will enable beam steering. Figure 3 demonstrates that an array configuration of interleaving transceivers suppresses sidelobe levels that in turn can enable a much better capability of image formation.

Two records of invention and associated patents have been filed: “Through Wall Motion Imaging, Tracking, and Discrimination of Multiple Human Heartbeats and Respiration Rates,” and “Fast Framing, Through Obstacle, Electronically Steerable Dynamic Radar Imaging Array.”

Related Reference

Chang, J., G. Azevedo, D. Chambers, P. Haugen, R. R. Leach, C. Paulson, C. E. Romero, A. Spiridon, M. Vigars, and J. Zumstein, "Ultrawideband Radar Methods and Techniques of Through Barrier Imaging," *IEEE International Symposium on Antennas, Propagation and USNC/URSI National Radio Science Meeting,* Monterey, California, June 20-26, 2004.

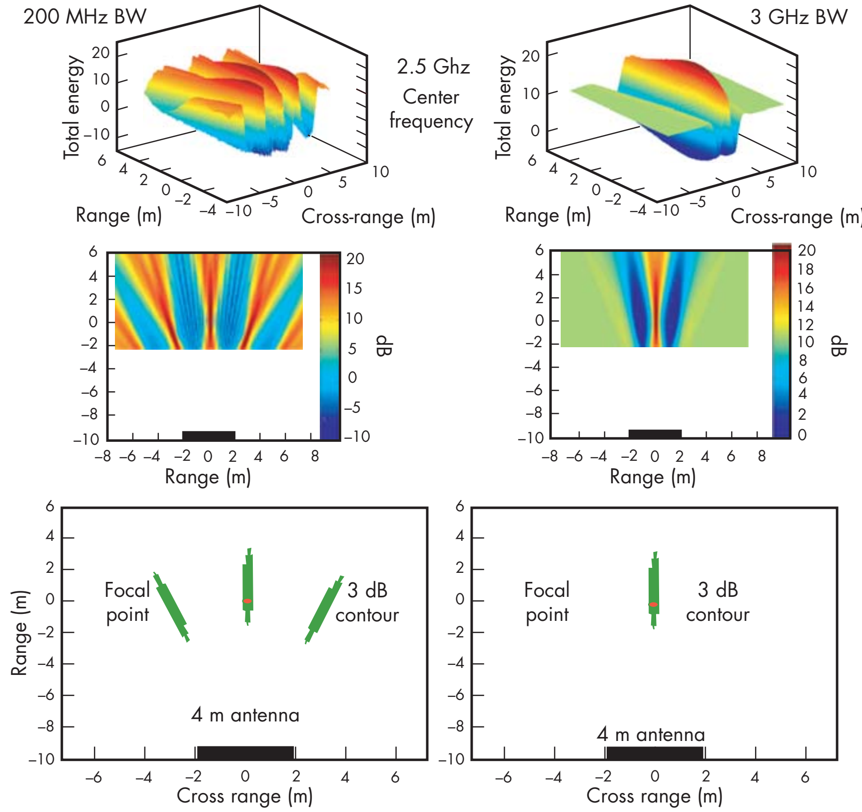

Figure 2. Example case comparison of the focusing ability of UWB signals as a function of bandwidth that will enable beam focus. Left column: narrow band signals cannot focus. Right column: UWB signals enhance focus.

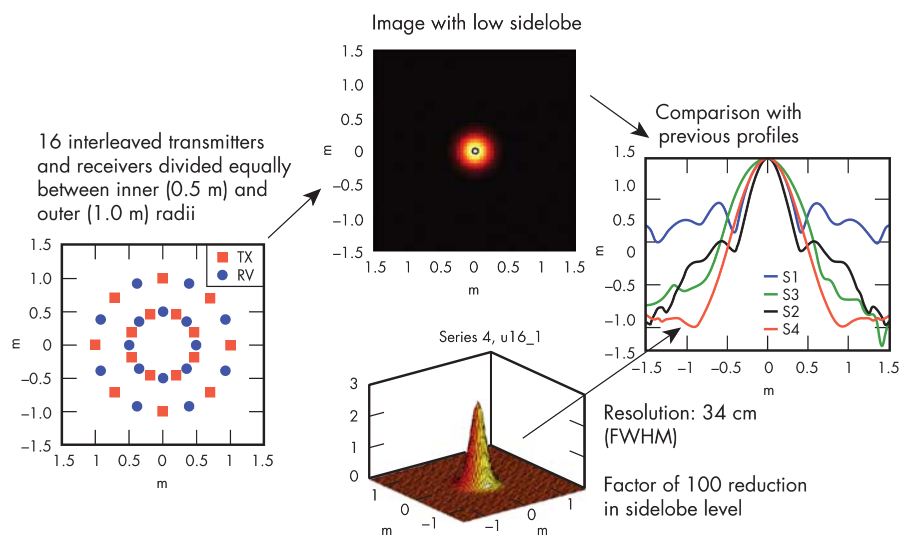

Figure 3. Example demonstrating the significance of array element distribution in suppressing the sidelobes that contribute to image quality degradations. S1 to S4 correspond to different element distributions of the antenna array. The configuration shown corresponds to S4.